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Improving Collision Energy Absorption In High Speed Train By Using Thin Walled Tubes

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Abstract

The purpose of this paper is investigating the effect and influence rates of utilizing thin walled energy absorption tubes for improving crashworthiness parameter by increasing energy absorption of the body in high speed railcars. In order to find this, a proper profile of available tubes is chosen and added to the structure of selected high speed train in Iranian railway network (Pardis Trainset) and then examined in the scenario of impact with other moving rolling stock. Because of the specific features of LS-DYNA 3D software at collision analysis, the dynamic simulation has been performed in LS-DYNA 3D. The results of the analysis clearly indicate the improvement of train crashworthiness as the energy absorption of structure increases more than 30 percent in comparison with the original body. This strategy delays and reduces the shock to the structure. The verification of the simulation is by using ECE R66 standard.

Keywords : *Crashworthiness, Thin walled tube, High speed train, Dynamic simulation, LS-DYNA 3D*

1. Introduction

One of the most common ways to increase the amount of energy absorption and improve crashworthiness parameter is using thin walled tubes with different profiles, specially square and rectangular profiles in vehicles with thin walled tubes as an energy absorber has been investigated frequently in recent years. Low weight and small size, availability, cost savings, and high energy absorption of tubes still cause widely usage of them as an energy absorber [1,2].

However, today because of the expansion of using rail transportation and increasing the capability of vehicles so the likelihood of accidents and mishaps in high speed has been increased. Also due to weakness in the modern safety systems such as signaling and failure warning system, unfortunately, the number of accidents on the Iran railway network is very much (see Fig. 1). Meanwhile, railway network is the one of major priority for executive programmers in transportation (passenger and freight) more than ever cause of increasing role and rate of it. So it needs essential special attention to improve the safety of rail transportation to reduce damages and save occupants lives.

Research in the field of vehicle safety is divided into two parts: the prevention of accidents and reduce injuries. These parts are called active safety and passive safety respectively. Active safety includes all preventive actions to prevent accidents, whereas passive safety includes all procedures that reduce the fatalities and injuries while accidents occur. Passive safety of the vehicles is directly related to structural crashworthiness of vehicle, which is the subject of this paper [3].

Fig. 1 shows procedure of rail accidents over years between 1999 till 2007, as obviously is shown in diagram most of accidents is in the case of derailment and rolling stock impact, so the most effective way to improve active safety on Iran railway network is using of modern technologies to reduce the occurrence of derailment and collision, but for optimizing of passive safety, improvement crashworthiness parameter of fleet is necessary. This issue has

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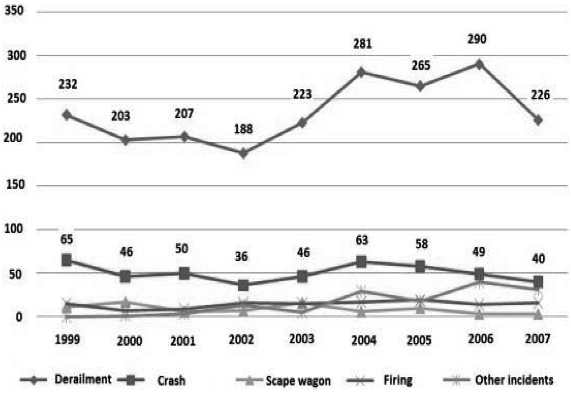


Fig. 1 Diagram of rail accidents in the years 1999-2007

been investigated in this paper by the authors [4].

The purpose of crashworthiness is designing a body for a vehicle that can absorb impact energy by a controlled deformation, while the survival space for passengers maintain. And also impact force transmission to the passengers while collision will be minimized [4].

The history of researches regarding the crashworthiness in rail collision is not wide enough, the researches carried out around using the thin walled tubes and foams in railcars in order to optimize the energy absorption are:

- Study of the crashworthiness of passenger trains at level crossing [5];
- Development of passenger train crush zone [6];
- A proposal for using foams in the nose section of high speed trains [10];

In general in this study has been tried to recommend an applicable and cost-effective way for improving the passive safety due to the ability and capability in the domestic rail industry, so the authors propose the design of an appropriate profile of the thin-walled tubes, and using of tubes in Iran Pardis Trainset are analyzed and evaluated.

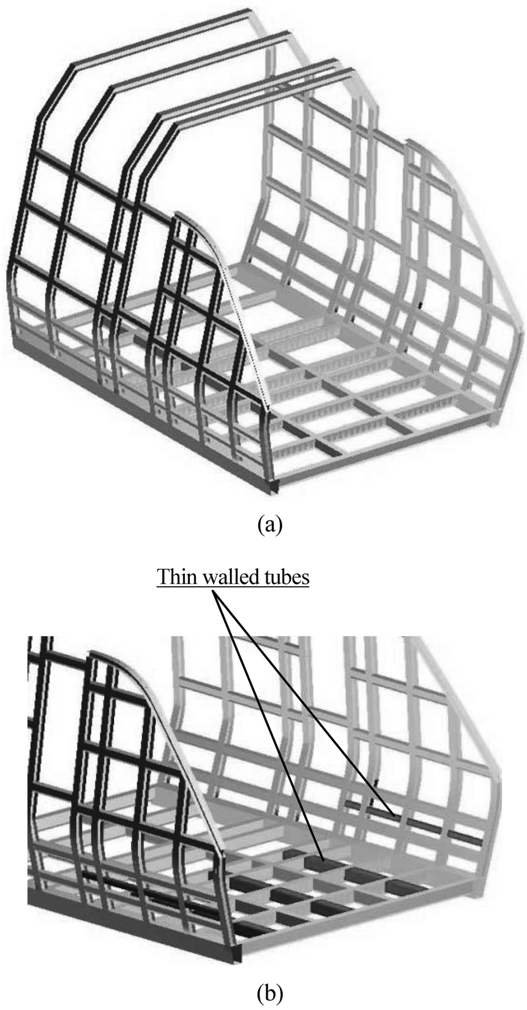


Fig. 2 The solid works model of Pardis Trainset body (a)Original body, (b) Improved body

2. Simulation

EN 15227:2008+A1:2010 standard is about Crashworthiness requirements for railway vehicle bodies; the design of new vehicles for use in passenger trains is based on operations with compatible rolling stock that also meet this standard. Four main scenarios of the most common accidents occurred in the railways, which are suggested by EN 15227: 2008 + A1:2010 Standard:

1. Head on collision of two high-speed trains
2. High-speed train collision with another rolling stock
3. High-speed train collision with heavy road vehicle
4. High-speed Train collision with road cars, objects… [7]

For modeling in this paper, Iran Pardis Trainset the fastest railcar in Iranian railway network under the second scenario is selected. Because:

1. The possibility of crash between two high speed trains (Iran Pardis Trainset) is less than the other recommended scenarios, (because the number of high speed train is lower than the others),

2. Railcar collision with road vehicles and other obstacles don't make major damage for rolling stocks or injuries for rail vehicle occupants.

Therefore crash between high speed train and other kind of rail vehicle was investigated.

In order to achieve optimum behavior in head on collision, all the impact energy must be dissipated and wasted by the frontal part of cabin. The minimum acceleration was transmitted to passenger compartment, when deformation at the front of the train will be as long as possible [8].

Thus, whit consideration to the EN 15227: 2008 + A1 standard criterions for impact areas [7], Pardis trainset nose and chassis was selected for thin-wall tubes installation. For designing the tubes, while square cross-section tube was chosen, due to different available space in the chassis and nose, for each parts tubes with different dimensions were designed.

The thickness of all tubes is 2 mm and it is in constant in the longitudinal direction. This thickness is a realistic value, which is usually can deform and fold with a pattern [8].

Three-dimensional model of the body have made by SolidWorks 2011 software and Abaqus / CAE 6.9-1 software uses for meshing the model. The other features of the simulation have been attributed to the model by LS-DYNA 3D finite element software, which has the ability to run the simulation very fast, in very small time steps. Fig. 2 – A shows the three-dimensional modeling structure and Fig. 2 - (b) shows location of the tubes in that structure. It should be noted for Tube locating in the body, kept at mind that structural asymmetry does not break down and also have maximum energy absorption by the tubes.

3. Verification

The vehicles field tests are very expensive and it takes much time and only at the last design stage when the modeling is close to being finalized, it can be done. Nowadays, with the development of computer aided engineering (CAE) techniques vehicle collisions process and crashworthiness can simulate fully, so for crashworthiness designing of vehicles, simulating of partial model and complete model of vehicle could be replaced with field test, thus substantially the development cost and time will be reduced [3].

Therefore in this study ECE R66 standard is used to evaluate the accuracy of the computer simulation. According to the standard computer modeling is correct when the following two conditions are satisfied:

1) The hourglass energy should be less than 5% of the total energy.

2) The energy ratio shouldn't exceed 1 ± 0.05 [5].

Fig. 3 shows a diagram of the total energy and hourglass energy in the same chart. According to this chart it is clear that the hourglass energy is in the specified range in the standard. The Maximum of hourglass energy (51,240 J) is equal 1.28% of total energy (4 mega joules). So the first requirement of standard is confirmed.

Fig. 4 shows the energy ratio parameter versus time. The second standard is clearly satisfied, accordingly. As energy

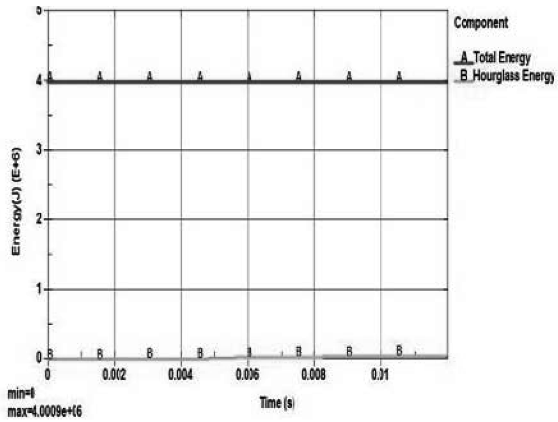


Fig. 3 Diagram of energy versus time

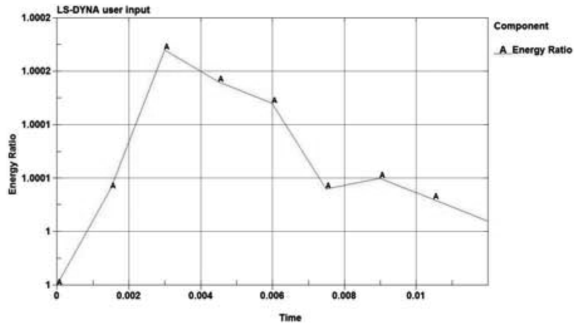


Fig. 4 Diagram of energy ratio versus time

ratio parameter is changing from 1 to 1.0002, this domain of changing isn't exceeding the limits mentioned in the standard. The second condition of standard is confirmed.

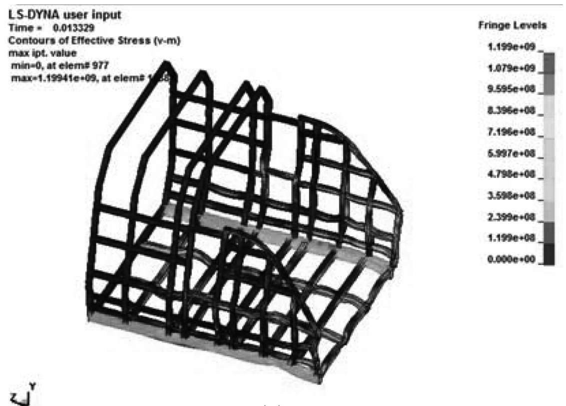
Thus, according to the conditions in Standard ECE R66, accuracy of computer modeling will confirm to these standards.

4. Results

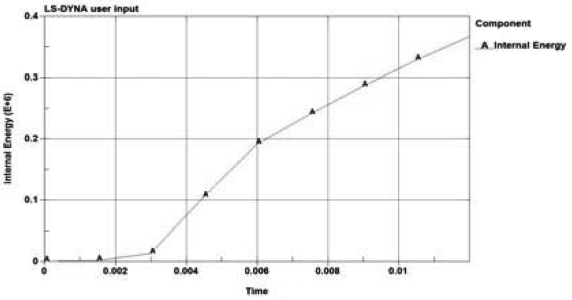
The amount of energy absorbed versus the time for the original structure (without tube) is shown in Fig. 5 – B. As indicated in that figure the total amount of absorbed energy by the structure is approximately 370,000. Fig. 3 – A shows the deformation caused by collision and the rates of stress while the impact.

The collision energy absorption after placing the designed tubes is shown in Fig. 6. as obviously seen in the diagram, the impact energy absorption in optimized structure with thin-walled tubes is 51,900 joules more than energy absorption in initial structure, which is equivalent to 14.28% of total energy absorption in the primary structure.

But due to design long tubes against the cross-sectional



(a)



(b)

Fig. 5 after collision: (a) Structural deformation after collision, (b) Energy absorption vs. time

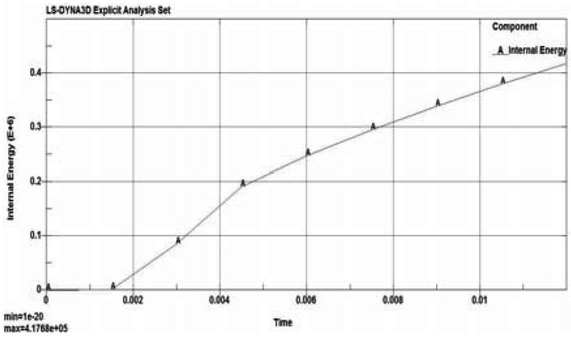


Fig. 6 energy absorption of optimized structure vs. time

of the tubes, so tubes haven't enough resistance against shock and fractures occur on tubes. So change in Tube Crush pattern is the result, that causes reduce the energy absorption by tubes. Because energy absorption in thin Walled tubes is not related to material properties only, also it depends on the geometrical characteristics and folding and deformation pattern of tubes [9].

Thus, to obtain an optimize pattern of deformation and increasing energy absorption, by preventing the fractures in tubes while impact shock entered, short length of tubes

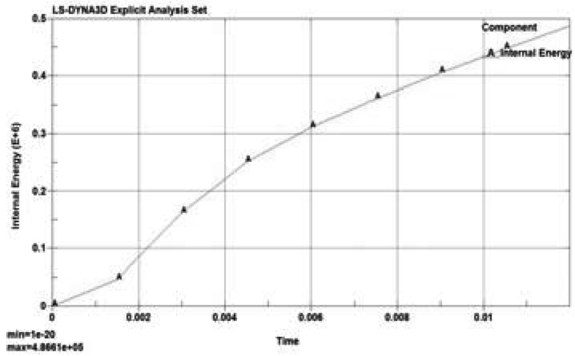


Fig. 7 energy absorption of optimized structure (with short tubes) vs. time

was designed and replaced in the body. The energy absorption diagram of the structure with the new and short tubes is shown in Fig. 7.

As seen in this diagram using of this shorter tubes, by better folding pattern and optimum crush, amount of energy absorption by the tubes in compare with longer tubes 689309 Joules increased which is equivalent 16.5% of total energy absorption of using longer tubes. And also in this case initial shock to passengers decreases rather than other cases abundantly.

And also in comparison with the original structure (without energy absorber tubes) total energy absorption 120830 Joules increases, which is equivalent to approximately 33 percent of the total energy absorption in the initial structure.

5. Conclusion

In this study, regarding to the high rate of accidents in Iranian Railway Network, which clearly shows weakness of safety in railway transportation, the effect of using thin-wall tubes to improve the crashworthiness of high-speed trains investigated which is directly related to passive safety. To achieve this goal, nose and frontal part of chassis of Iran Pardis Trainset (the fastest train in Iranian railways) based on recommended scenarios in EN 15227: 2008 + A1: 2010 standard and under 2nd scenario of this standard (head on collision between high-speed train and other rail fleets) has considered for investigations and studies.

Computer Modeling and dynamic analysis was performed by LS-DYNA 3D software. Due to the costs of the field test and limitations, validation of simulation has been done by ECE R66 standard criterions, and as the rates of hourglass energy and energy ratio were matched with the standard conditions, so verification of simulation has been confirmed.

The results of the dynamic analysis indicate that using thin-walled tubes significantly increases total energy absorption and energy absorption at the initial moment of impact. So that total energy absorption after optimizing the structure by these tubes increases more than 33% compared to the initial structure.

Therefore, because this method does not require extensive and costly changes in the initial structure, domestic capability to installation of thin-wall tubes in Rolling Stocks and Significant effect on the improvement of passive safety, Using these tubes in the high-speed train of country railways has been proposed.

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